A Snowball's Chance in Hell

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As the Sun evolves, a wave of quickening passes through the Solar System. That this will happen is well-known and it has been discussed in several papers in the literature. The usual subjects of interest are the pasts of Venus and Earth, and the futures of Earth and Mars (which will eventually terraform itself without gubernatorial intervention, if it's got the right stuff). It has also been pointed out that for a brief shining moment the red giant Sun will defrost Titan's organic soup, and will even very briefly make comets of the Kuiper Belt, neatly inverting today's story. After its first trip up the red giant branch, the Sun spends 100 million years burning helium on the horizontal branch. During this time, sunshine at Jupiter's icy moons will be much the same as it is at Earth today. Imagination paints a mythic vision of celestial boats sailing shining seas, a post-red-giant idyll before the final apocalypse. But can icy moons pass through the red giant hell to enter the promised afterlife? This paper will discuss how well strongly insolated water worlds retain their water. In very broad brush, a world has three options for dealing with sunlight: it can heat up, it can radiate the equivalent amount of energy to space from a photosphere, or it can evaporate and shed matter to space. The long-term solution is radiative balance and that is what one usually sees. But the red giant Sun is not effectively opposed by radiative cooling by water vapor. Escape is then rapid and efficient. For a free-floating planet the water vapor is lost, but for satellites of Jupiter the hot water vapor is gravitationally bound in a disk that orbits the planet. The disk is as big as the satellite system. When the Sun descends to the horizontal branch, the water can return to any moons that survive. We construct a simple model of a planetary wind that accounts for radiative heating, radiative and mass loss coolings, and the background pressure exerted by the nebula. The impact of the solar wind and satellite surface conditions through the red giant phase are considered. We note that planet migration can cause similar untoward increases of insolation of icy worlds. This raises the possibility of fairly long-lasting observable consequences of chaotic dynamical rearrangements of planetary systems that in principle could occur at any time.